Red Clay Creek

Nutrient concentrations, flow rates, and mass loads (the product of the average daily flow rate and nutrient concentration) were examined for three stations along the mainstem Red Clay Creek (Table 5). Data on the West Branch Red Clay Creek collected during low-flow surveys in 1997 were also examined and compared to the mainstem data. Time series graphs of flow rates and nutrient concentrations were first developed using all the data at each station. To examine any changes or trends at low flow conditions, time series graphs were developed for nutrient concentrations and mass loads at flow rates less than the annual 20^{th} percentile flow. The time series graphs of nutrient concentrations and mass loads for each station are presented in Appendix D.

Table 5. Stations and data availability for the Red Clay Creek low flow analyses.

Stream Reach	Gage Number	Location	Data Available
Mainstem Red Clay Cr	1479820	Marshall's Bridge at confluence of East & West Branches	Nutrients, Flow (PA-DEP)
Mainstem Red Clay Cr	1480000	Woodale	Nutrients, Flow (DE-DNREC)
Mainstem Red Clay Cr	1480015	Stanton	Nutrients, Flow (DE-DNREC)

Nutrient Concentrations and Mass Loads

As noted above, the time series graphs of nutrient concentrations and mass loads for the Red Clay Creek are shown in Appendix D. A Mann-Whitney test was conducted on

the low flow data set to determine any statistically significant changes in concentrations or mass loads over time. The results of these analyses are summarized in Table 6 (statistically significant changes at the 0.05 level are indicated with "**"). The nutrient concentrations and mass loads were fairly stable at each station over the period of record (1988-1997 at Marshall's Bridge, 1980-1997 at Woodale, and 1990-1997 at Stanton). The only significant changes detected were a slight decrease in NH3-N concentrations and mass loads at the Woodale and Stanton stations. A summary of the low flow nutrient concentrations and mass loads (median, upper and lower quartiles, maximum, and minimum) at each station is presented in Appendix E.

Table 6. Summary of median nutrient concentrations and mass loads at low flow conditions for the Red Clay Creek. (** denotes a statistically significant change at a 0.05 level of significance).

Station	Period	TP mg/L	TP Load lb/d	SOP mg/L	SOP Load lb/d	NH3-N mg/L	NH3-N Load lb/d	NO3-N mg/L	NO3-N Load lb/d
Marshall's Bridge	88-92	0.62	46.5	0.43	36.0	0.03	2.00	5.08	444
	93-97	0.55	32.9	0.46	31.7	0.03	2.25	4.85	351
Woodale	80-92	0.35	38.2	0.24	31.0	0.10	10.6	2.87	260
	93-97	0.31	31.0	0.26	27.2	**0.03	** 3.0	2.64	286
Stanton	88-92	0.29	39.2	0.180	25.9	0.05	7.6	2.68	372
	93-97	0.23	25.2	0.175	20.1	** 0.03	** 2.4	2.22	275

Figures 24-27 show the spatial profiles of nutrient concentrations and mass loads at low flow conditions over the last 5 years along the Red Clay Creek. In all cases except ammonia nitrogen, the highest nutrient concentrations and mass loads occur at the most upstream station (Marshall's Bridge). Results of the 1997 low flow surveys on the West Branch Red Clay Creek (Davis 1998) show that the West Branch is contributing 72% of

the median low flow phosphorus load at Marshall's Bridge (26 lb/d total phosphorus from the West Branch) and 46 % of the nitrate nitrogen load at Marshall's Bridge (159.4 lb/d nitrate-nitrogen from the West Branch). The high phosphorus load in the West Branch is mainly due the discharge from the Kennett Square wastewater treatment plant. The nitrate concentrations at Marshall's Bridge are similar to those in the West Branch, both above and below the Kennett Square discharge. This suggests that the relatively high nitrate nitrogen concentrations are representative of background conditions which exist in the groundwater providing baseflow to the stream throughout the upper watershed.

Dissolved Oxygen Concentrations on the West Branch Red Clay Creek

The only data set of continuous dissolved oxygen data on the Red Clay Creek was collected during the 1997 low flow surveys on the West Branch (Davis, 1998). Continuous DO monitors were set a several stations above and below the Kennett Square wastewater discharge. Figure 28 shows the temporal DO profiles for a station located above the discharge (M2), a station located just below the discharge (M3), and a station located approximately 1.5 mile below the discharge (M5). The graph shows that the dissolved oxygen concentrations are severely depleted moving downstream from the discharge due to the high wasteloads of organic and nitrogenous oxygen demand from the Kennett Square wastewater discharge. The data from the downstream station also shows a larger variation in DO concentrations over the course of a day, and this is due to the increased photosynthetic activity related to the high nutrient concentrations in the stream.

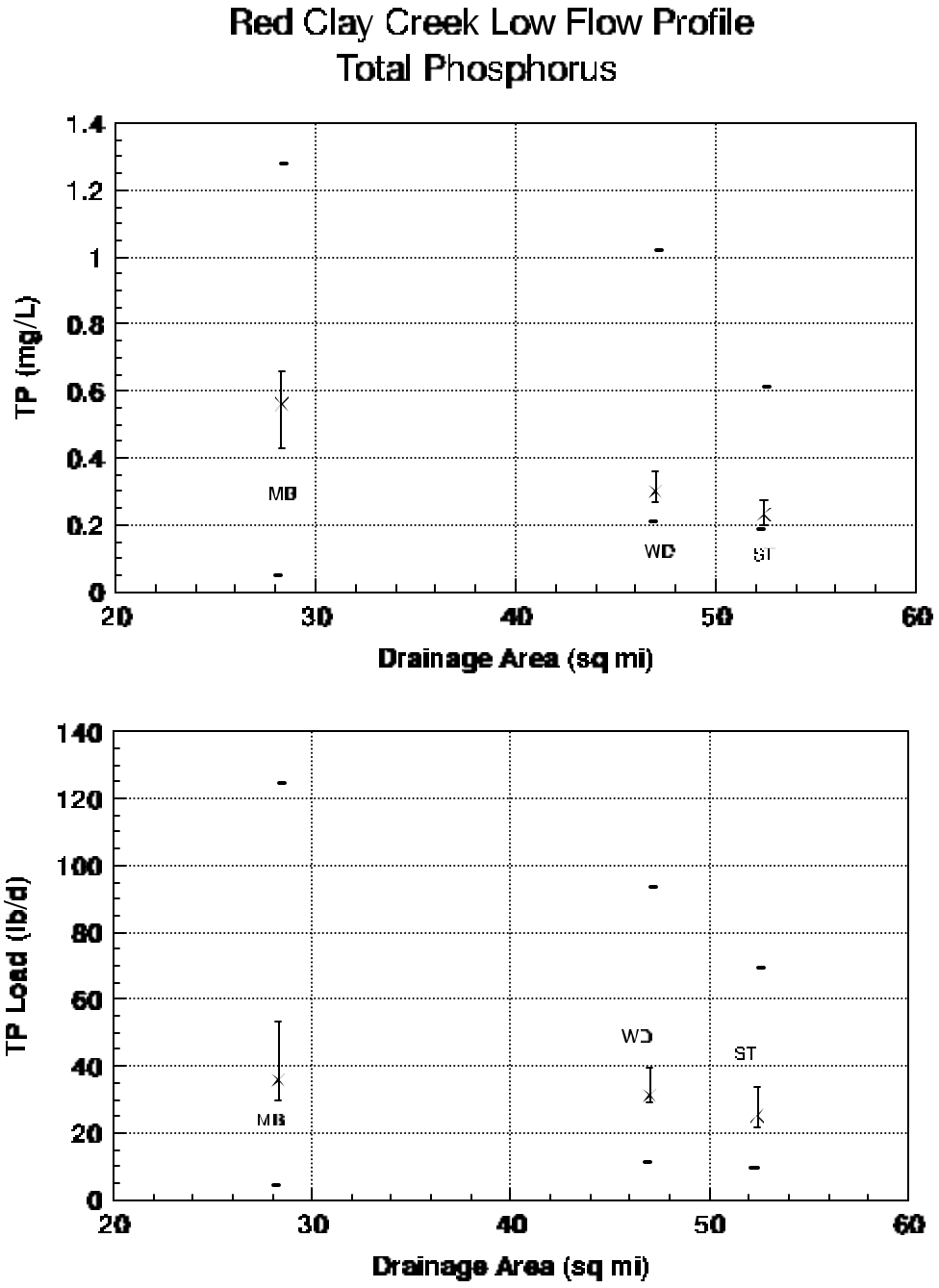


Figure 24a and b. Total phosphorus concentrations and mass loads at low flow conditions in the Red Clay Creek as a function of drainage area (MB= Marshalls Bridge, WD= Woodale, and ST= Stanton).

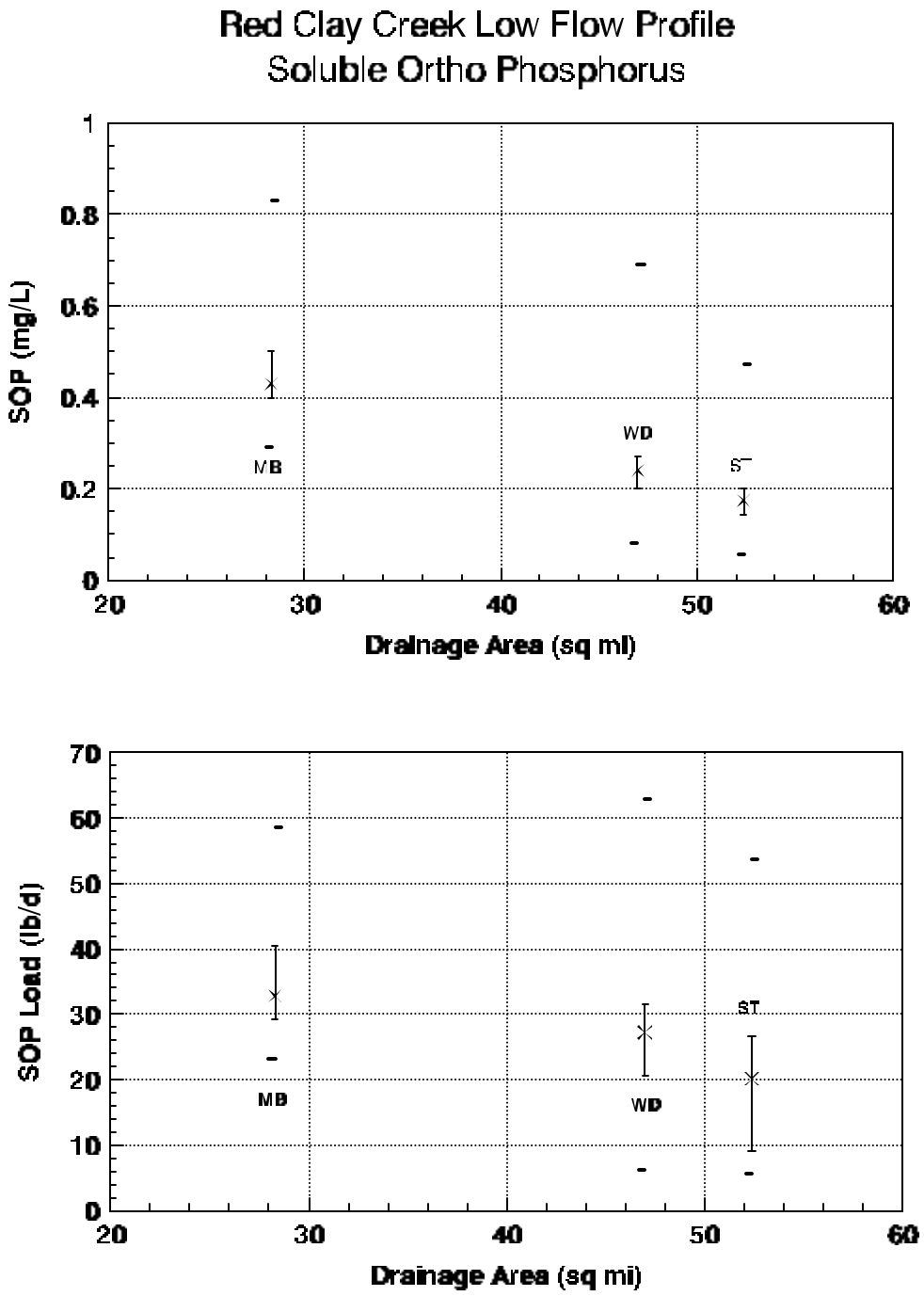


Figure 25a and b. Soluble ortho-phosphorus concentrations and mass loads at low flow conditions in the Red Clay Creek as a function of drainage area (MB= Marshalls Bridge, WD= Woodale, and ST= Stanton).

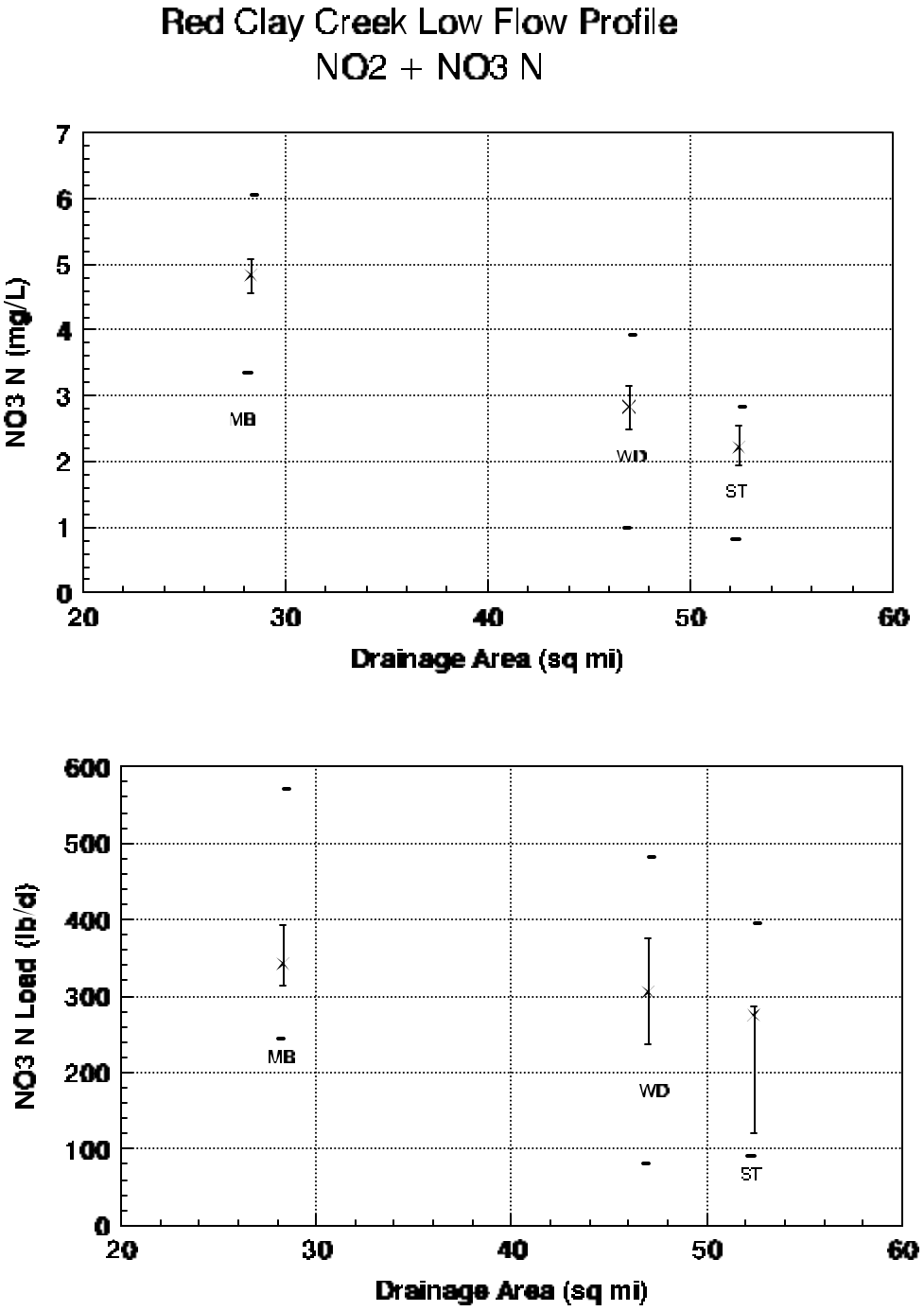


Figure 26a and b. Nitrate-nitrogen concentrations and mass loads at low flow conditions in the Red Clay Creek as a function of drainage area (MB= Marshalls Bridge, WD= Woodale, and ST= Stanton).

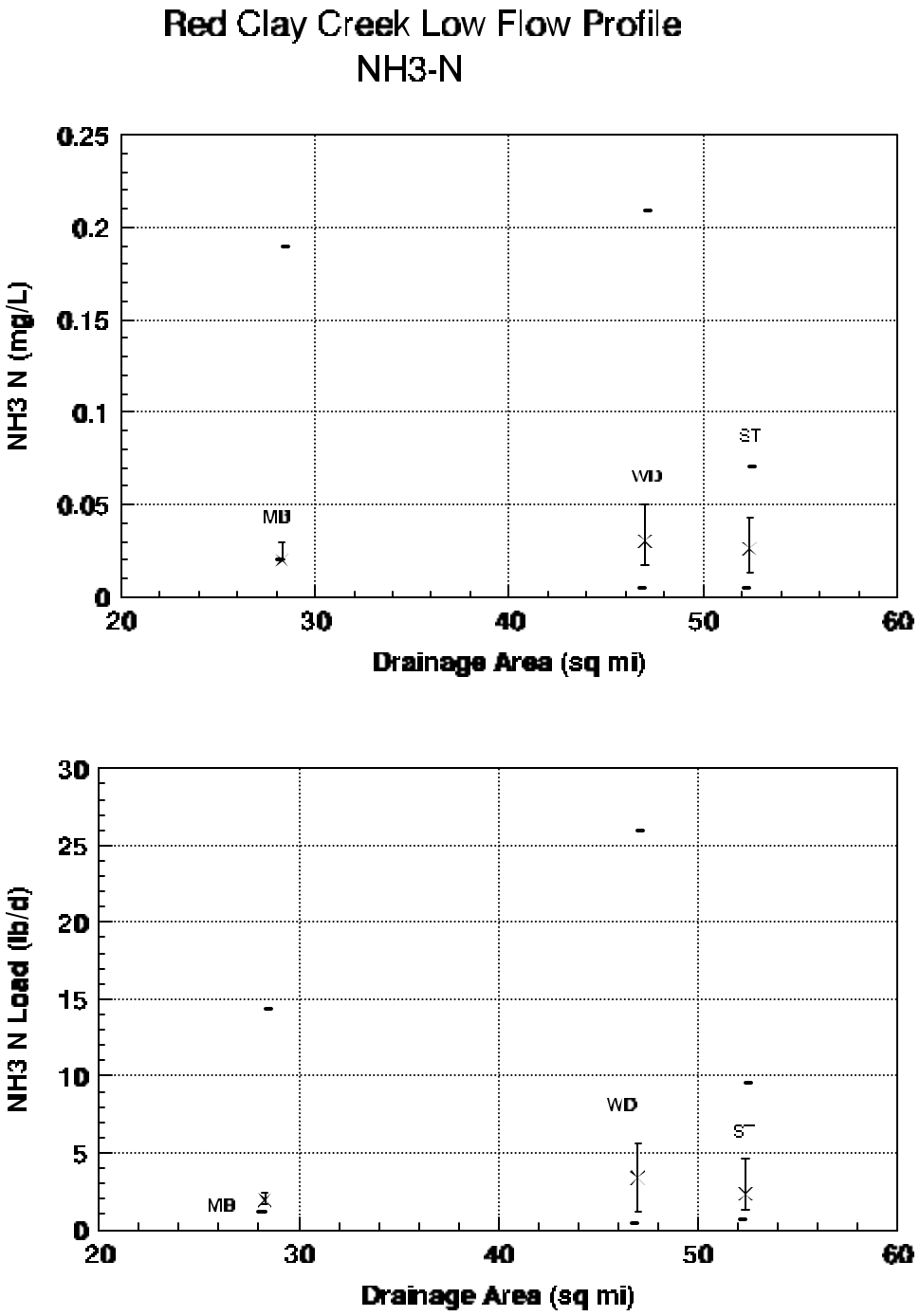
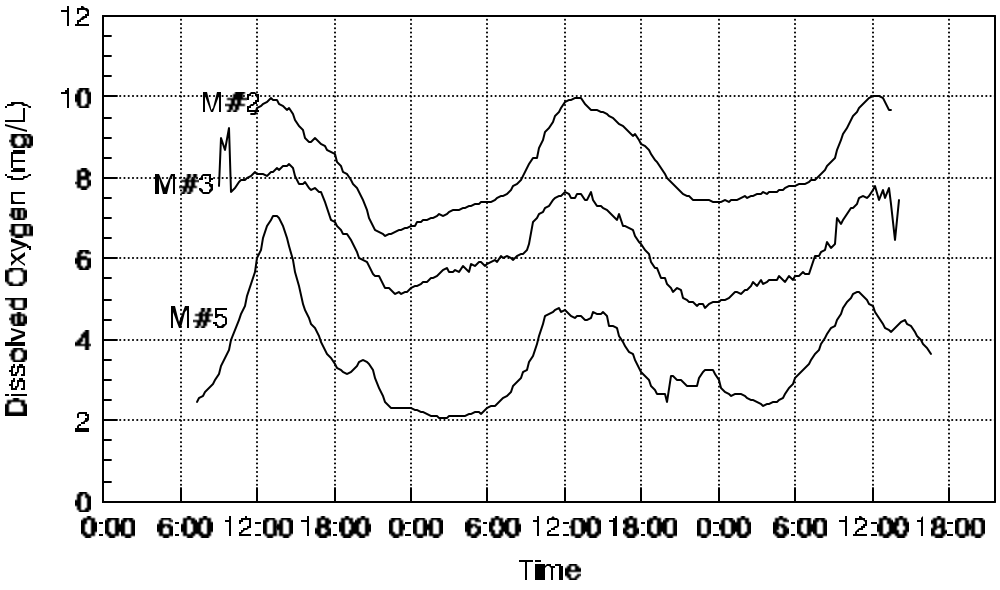


Figure 27a and b. Ammonia-nitrogen concentrations and mass loads at low flow conditions in the Red Clay Creek as a function of drainage area (MB= Marshalls Bridge, WD= Woodale, and ST= Stanton).



Note: M#1-M#3 data from 8/5-7/97; M#4-M#5 data from 8/12-14/97.

Figure 28. Dissolved oxygen profiles for the West Branch Red Clay Creek from low flow surveys conducted during August 1997. (M2 – above Kennet Square discharge, M3 – about 0.25 miles below Kennett Square discharge, and M5 – about 1.5 miles below Kennett Square discharge).

Summary of Findings for the Red Clay Creek

Nutrient concentrations during low flow conditions throughout the West Branch and mainstem Red Clay Creek are relatively high, and are the highest among the major tributaries making up the Christina Watershed. Nitrate-nitrogen concentrations during low flow appear to be high throughout the upper watershed (East and West Branches), and this most likely related to nonpoint source nitrate loads in the groundwater providing baseflow to the stream. High phosphorus concentrations in the West Branch are primarily due to the Kennett Square wastewater discharge. Nutrient concentrations and

mass loads generally decrease moving downstream from the Marshalls Bridge station at the confluence of the East and West Branches.

The dissolved oxygen concentrations in the West Branch below the Kennett Square discharge are depleted below the water quality criteria (minimum DO of 4.0 mg/L) due to the high organic and nitrogenous oxygen demanding wasteloads from the Kennett Square wastewater treatment plant. Increased photosynthetic activity was also noted in the West Branch below the discharge.